3D Virtual Reconstruction and Visualization of the Petit Trianon in Versailles

Noémie Renaudin (UMR CNRS/MCC 3495 MAP-Gamsau, France)

Bertrand Rondot (Etablissement Public du musée et du domaine national de Versailles, France)

Livio De Luca (UMR CNRS/MCC 3495 MAP-Gamsau, France)

It is difficult to grasp the complex history of the successive changes of the furnishings and layout of the Petit Trianon. Our ongoing project addresses this challenge. Based on 3D digitizing, high photorealistic rendering, real-time visualization and spatio-temporal data structuring, our approach provides more than a straightforward 3D model of the rooms: it ensures that the contents of the rooms are not fixed in their current state, but enhanced on the basis of additional perspectives. The refurnished virtual rooms are, paradoxically, more realistic. Freed from the constraints imposed by visitor traffic and security, they are presented not in their existing fragmentary state, but as a completed whole. Our data structuring method also enables the user to explore the consecutive changes of the furnishings over time (integrating furniture which today is conserved in different museums worldwide) and thus provides a dynamic vision of the Petit Trianon's spaces. The current project focuses on the 3D reconstruction and virtual visualization of the rooms and their furnishings in their current state.

Today it is possible to discover a historic site not just in its current state but through its successive occupants and developments over time. The château of the Petit Trianon is above all associated with Marie Antoinette (1755–1793), whose time is still predominant in the eyes of most visitors. But this place witnessed different periods and different people with different tastes, and the corresponding changes to its furnishing also deserve to be revealed to the public.

The Petit Trianon was inaugurated by Louis XV and Madame Du Barry in 1768. In 1774 the new King Louis XVI gave it to his Queen Marie Antoinette, who made it her favourite place. She first devoted herself to landscaping and in the 1780s began to renew its furniture. Emptied during the Revolution, the château was finally taken over by Napoleon in 1805 to house his sister Pauline Bonaparte, Princess Borghese. But it was for the Empress Marie Louise, married in 1810, that most of the new pieces of furniture were provided. During the Restoration the place remained uninhabited, and afterwards the furniture supplied under the Empire was completed in the new

romantic taste. The fall of the July Monarchy in 1848 led to the abandonment of the Petit Trianon as a residence and it was during the Second Empire, in 1867, that the Empress Eugenie installed there a museum dedicated to the tutelary figure of the place, Marie Antoinette.

This complex history is difficult to grasp by the public. The current presentation focuses on the time of Marie Antoinette on the first floor and mentions the succession of its various occupants in the attic. Thanks to the 3D digital representation, the château can be virtually refurnished with great accuracy and in accordance with successive historical states. The virtual tours of the furnished rooms allow one to discover the varying tastes of its occupants at different times.

Objectives of the Model

The model is more than a mere transposition of the rooms into 3D views. The digital model allows to represent not just the collections that are actually visible on site, but to further enrich this content along complementary axes.

First, the virtual refurnishing is, paradoxically, more realistic. The furniture finds its natural location and the virtual visitor can move freely through these spaces, without the constraints of safety regulations or the flow passages reserved for groups. Moreover, when certain elements of a set (for example, a set of chairs) are lost, the set can be virtually completed by duplicating a 3D model of the preserved element.

Second, groups of objects that have since been scattered around the world are reunited virtually. Some pieces of furniture and other objects are now preserved in different museums abroad. With the exception of a flat desk made for Louis XVI (which is now in the J. Paul Getty Museum in Los Angeles and was temporarily loaned to the Petit Trianon) it is usually impossible to bring these objects back, but they can be digitized and virtually replaced in the room for which they were conceived. For example, a mechanical table preserved in Waddesdon Manor (Great Britain) was among the first pieces of furniture ordered by Marie Antoinette for the Petit Trianon; its return is virtually possible with the 3D digital representation.

Third, broken-up furniture can be reassembled virtually. A modified piece of furniture can be returned to its original state by modelling the several scattered elements. This is the case of a table with sliding top, belonging to Marie Antoinette: only its top is preserved (in the Victoria and Albert Museum in London) but its base type is known from other copies.

The digital representation must also be able to deal with the chronology of consecutive furnishings in a dynamic vision of the spaces. Thus the bedroom of Marie Antoinette, originally used by Madame Du Barry, was later occupied by Pauline Borghese, then by the Empress Marie Louise, and finally by the Duchess of Orleans. Some pieces of furniture were retained from one period to the next, while others were replaced by more modern furniture. The virtual visitor can view successive furnishings, according to chosen chronological marks, and corresponding to dif-

ferent inventories: a first state in 1780 (after the first orders placed by Marie Antoinette and before the full refurnishing of her apartment in 1787–88); a second state in 1811 (corresponding to the inventory drawn up by the Empress Marie Louise in 1810 and completed in the following year); and a third state in 1839 (corresponding to the inventory drawn up by the Duchess of Orleans).

Data Acquisition and 3D Reconstruction

The main idea of this work is to provide a virtual tour of these furnishings coupled with an interactive database. It presents not only the technical and historical information of each object or piece of furniture, but also allows to manipulate each element in space, so that the user can see moveable parts in different states (for example by virtually opening a writing table's desktop or drawer) and discover hidden details (such as inventory numbers marked under the seats). The basis of this project is therefore the integration of the techniques of digitizing, geometric reconstruction and 3D visualization.

3D Digitizing of Rooms

The interior spaces of the rooms are digitized using a 3D phase-shift laser that can acquire up to 100,000 coordinates per second. Point clouds resulting from this acquisition are assembled to make a precise geometric model of the existing spaces (fig. 1). In addition, a high-definition photography campaign has recorded the surfaces' visual appearance (fig. 2).

Fig. 1 Point cloud obtained by laser scanning of room.

Fig. 2 High-definition photographic acquisition.

The 3D reconstruction of the rooms is based on an interactive geometrical modelling starting from relevant profiles extracted from the point cloud. The linking of the geometric model of the spaces with all the photographs allows one to reconstruct the visual appearance of the surfaces by projecting textures taken directly from these photographs (oriented on the 3D model by resection).

3D Digitizing of Furniture

Apart from surveying the architectural volumes, the project comprises the digitizing of figural objects and pieces of furniture that are now preserved in different places. The geometry and texture of 91 elements, located in France and in the United Kingdom, have actually been acquired. Other campaigns are being organized in the United States. The 3D digitizing was performed with a triangulation laser which acquires shapes with millimetric precision and a high-definition camera. Different 3D reconstruction techniques (automatic meshing, image-based modelling, reconstruction by parametric surfaces, and so on) are implemented in function of the morphological complexity of the object and the nature of its materials.

- **Laser-based modelling**. In the case of the restitution of sculpted objects such as busts, point clouds were automatically obtained by common meshing algorithms. Meshes of resulting models contained between 100,000 and 400,000 polygons, providing a very accurate reproduction of the complex geometry of the object. In order to enhance the visual aspect of the objects, an 'ambient occlusion' rendering was realized and its result was assigned to each vertex of the mesh (fig. 3).

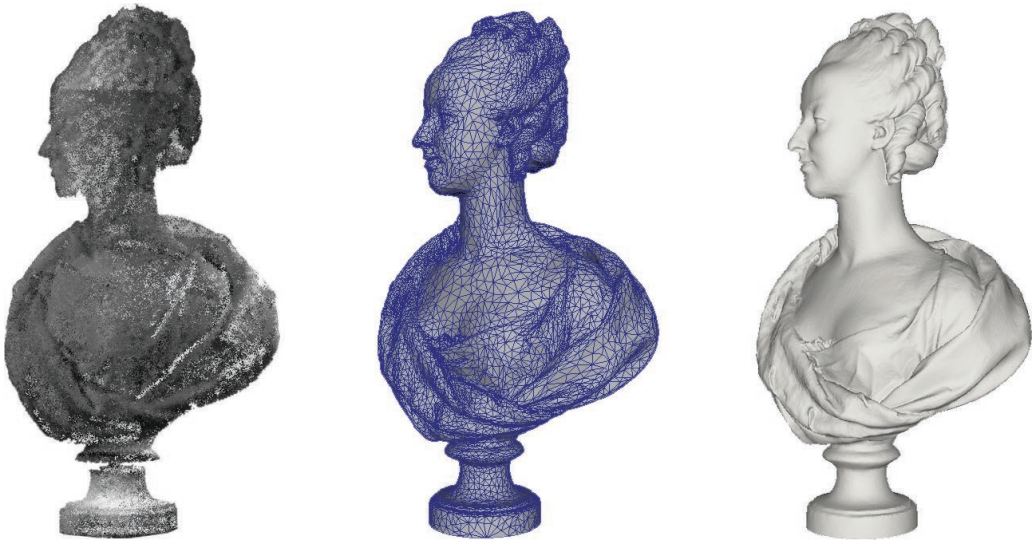

Fig. 3 Steps of laser-based modelling: point cloud, geometry, ambient occlusion render.

- **Image-based modelling:** The 3D reconstruction by image-based modelling is perfectly applicable to most objects with a more 'simple' geometric structure. This modelling system is used to extract the 3D geometry of the object based on the determination of matching points between the different pictures of this object. The links established between photos during the calibration phase allow extracting textures from one or more images, which are then projected onto the model to reproduce the visual appearance of the object. Using image-based modelling provides 3D models with a geometric structure adapted to multimedia broadcasting but responding also to the requirements of visual rendering and extraction of dimensional information (fig. 4).

Fig. 4 3D reconstruction by image-based modelling.

- **Hybrid (laser/image) modelling:** Some kinds of objects, because of their complex geometrical structure, require a combination of treatments. In this case it is necessary to separate the different parts of the object based on their structure and their materials so they can be treated independently. The structure of the object is processed by image-based modelling or interactive modelling starting from relevant profiles and 3D coordinates, while the laser-based modelling is used for the sculpted part, on which is applied a material in order to reproduce its visual appearance (fig. 5).

Fig. 5 Example of hybrid reconstruction using interactive modelling and laser-based modelling.

As a result, this project presented an opportunity to assess the relevance of the most appropriate reconstruction methods according to the heterogeneity of the treated objects (fig. 6).

Fig. 6 3D reconstruction methods: **a.** Laser-based modelling, **b.** Image-based modelling, **c.** Interactive modelling, **d.** Hybrid modelling, **e.** HD photography.

Interactive Visualization

3D Database

All acquired information and data developed during the surveying campaign and the geometric reconstruction are structured and stored in a 3D database developed under the project NUBES (http://www.map.archi.fr/nubes). The database, developed in MySQL, retains four types of information: documentary, raw surveying, data processing, and optimized files for 3D visualization in real time. An interactive 3D scene, developed in Virtools DEV, allows the visualization and the handling of 3D representations.

- *Documentary and historical information* inserted by cultural institutions (mainly curators of the Public Establishment of Versailles); the data associated with each element are in connection with the management software of the collections of the Palace of Versailles TMS (The Museum System).
- *Raw surveying data* collects all the files included in the surveying process: 3D laser files (Point clouds), High Definition pictures, and so on.
- *Data processing files* concerning modelling software files (Maya, ImageModeler, Nubes, Rapidform) and textures files for restitution of the visual appearance (JPEG, PNG, and so on).
- *Optimized files for 3D visualization* used in particular in the part of the database allowing the handling of representations in real time.

Virtual composing of 3D scenes

The 3D restitution of the rooms is based on an approach of virtual furnishing guided by the assumptions made by the curator. A photographic environment (fisheye) representing the external environment is first added to the representation of the geometry of the rooms, then digitized pieces of furniture are integrated, and finally a lighting transport calculation is performed to merge the 3D renders of the rooms and furniture based on a common illumination condition (fig. 7).

Fig. 7 Virtual composing of 3D scenes (render of the room, addition of the external environment, integration of furniture, lighting transport calculation).

Fig. 8 Interactive scenes: example of 3D restitutions of rooms.

The interactive scenes are the result of the use of panoramic images with cubic projection oriented in a 3D scene containing the envelopes of objects (fig. 8). As all elements of the scenes keep a constant link with the 3D database, it is possible to display and manipulate, in this space, a selected element in the scene, to access all its information (technical, documentary, and so on), and also to search and collect items based on spatial, temporal and/or semantic criteria (fig. 9).

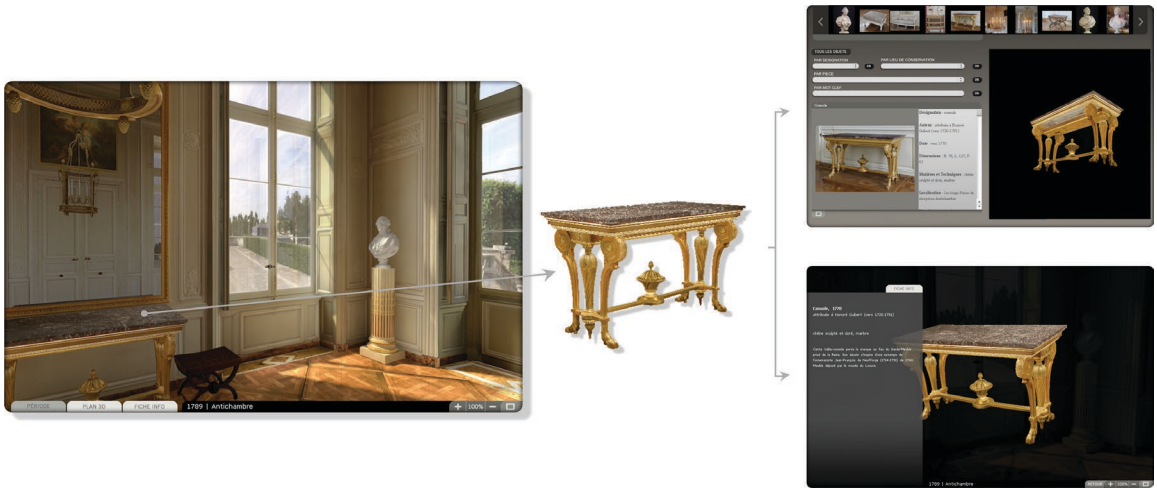

Fig. 9 Link between furniture of interactive scenes and 3D database.

Interactive Uses

The development of this system of interactive visualization has been chosen according to two main purposes, defined with MCC and the Public Establishment of Versailles. This 3D representation of the rooms, coupled with the database, allows for two types of use:

- *Online and on-site use, as a complement to the visit.* The interactive visualization of rooms online or on-site, through interactive terminals installed on the ground floor, allows the public to virtually visit the rooms of the first floor. Visitors can also use it as a complementary cultural offer, giving access to more realistic restitutions of the furnishings and to documentary and historical information, and allowing them to handle the furniture and so to discover hidden aspects.
- *Online use of an internal version of the database for storage and conservation of 3D data, pictures and documentary information.* Researchers, historians and curators involved in the project can use the database to consult the data already online, or to add/modify for each piece of furniture elements such as its documentary and historical information, photographs, name, place of conservation, or inventory number.

Future Steps

The next step concerns the modelling of the Queen's room and its evolution in Marie Antoinette's time at the end of the eighteenth century, and in the nineteenth century, when it was necessary to refurnish the palace that had been emptied by the Revolution. Marie Antoinette did make changes to the furnishings of this room by ordering the furniture '*aux épis,*' which has now been returned. In order to complete it, elements conserved in foreign museums will be modelled, in particular a chair preserved at the Getty Museum in Los Angeles. But the preceding furnishing must also be mentioned. Pieces of furniture which have not been found, such as seats, will be highlighted by a specific graphic processing. Fortunately, some pieces of furniture are known, such as the mechanical table preserved at Waddesdon Manor, which has already been modelled in the database. The user will be able to visit two successive states ordered by Marie Antoinette, which will show the evolution of her taste and fashion.

After the sale of the furniture during the Revolution, the bedroom, like the rest of the Petit Trianon, was completely refurnished for the Empress Marie Louise in 1810–11. This furniture has been preserved and will also be modelled. But unlike the previous state, which focused mainly on digitizing furniture, the restitution of these furnishings needs to take into account many textile elements, in particular the hangings and drapes that were especially created for the room and which covered its ceiling and walls, giving the room a tent-like appearance. It will be a challenge to define and implement the surveying techniques and data processing methods that are most appropriate for reconstructing this particular aspect.

Finally, the latest changes to the furniture were brought about by the Duchess of Orleans in the 1830s. The white satin drapes of Marie Louise were replaced by blue ones, and the aspect of the room was radically transformed. One of the challenges in modelling this phase will be to reconstruct this change of textile on seats that were conserved from one reign to the next.

Conclusion

In addition to detailed reconstructions of the Petit Trianon's rooms and furnishings, this ongoing project also takes into account a temporal and historical dimension. In fact, visitors can discover a new interaction with places and objects which until now could only be partially accessed and known about. Based on the application of tools and techniques that are used and developed in the laboratory, this project is part of the process of conservation and scientific investigation of the site, but responds also to recovery concerns and constitutes an innovative communication tool.

More information about the project is available on its website:
http://www.map.archi.fr/3D-monuments/site_trianon

Bibliography

Debevec, Paul, Taylor, Camillo, Malik, Jitendra, 'Modeling and Rendering Architecture from Photographs: A hybrid geometry and image-based approach', in *SIGGRAPH* (1996), pp. 11-20.

De Luca, Livio, Busayara, Chawee, Stefani, Chiara, Véron, Philippe, Florenzano, Michel, 'A semantic-based platform for the digital analysis of architectural heritage', in *Computers & Graphics*, 35 (2011) 2, pp. 227-241.

De Luca, Livio, Véron, Philippe, Florenzano, Michel, 'Reverse engineering of architectural buildings based on a hybrid modeling approach', in *Computers & Graphics*, 30 (2006) 2, pp. 160-176.

Levoy, Marc, 'The Digital Michelangelo project', in *The 2th International Conference on 3D Digital Imaging and Modeling* (1999).

Illustrations

Fig. 1-9 All illustrations by the authors.